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City Transport Monitoring and Routes Management System

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Introduction

Fast improvement of computers, automation systems, communications, mechatronic means allows *Intellectual Transport Control Systems* (ITCS) [1-4] to develop rapidly, which gives a possibility to optimally use ***existing*** infrastructure of city transport, and for the road users to choose the best (in accordance with the criteria chosen by the driver: *time*, *fuel consumption*, *accident risk* and etc.) route in the current situation.

Most of all traffic route optimal criterion is their transit time.

The optimal time of track overcome is the most important criteria for many drivers.

To find the shortest in respect of time (the fastest) rout one essential addition to the nowadays available GIS-TMC [2] system would be enough: a dynamic (automatically updated in real time) *street passing duration base* should be created.

Unfortunately, support of *street passing duration base* is impossible without creation of transport monitoring system operating in real time and consisting of sensors network, data collection communications system and data processing system. The structural diagram of such system is shown in Fig. 1.

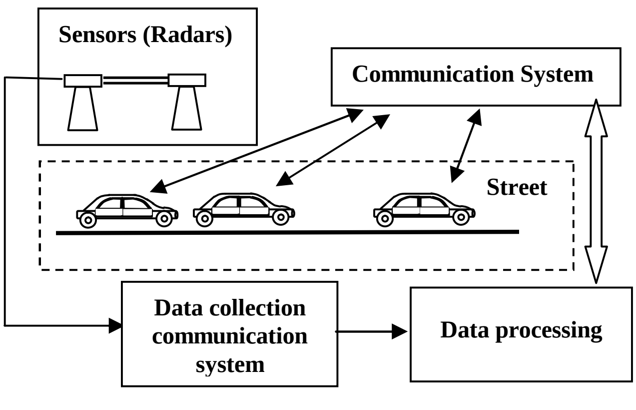

Fig. 1. Structural diagram of GIS-TMC system

The system structure is mostly determined by the range of informational sources. In common case the basis of the data processing system database contains fixed data:

- road and street network;
- fixed parameters of roads and streets (length, speed limit, changes of traffic density during the day, etc.).

Unpredictable changes of infrastructure parameters are registered after receiving the information from sensor network. The registered data and their changes are processed by data processing system, after that they are passed to the road users by radio channels (through automobile or pocket PC – communicators, radio or stationary information boards).

Street passing time

The street $\boldsymbol{G}_{ij}$, which length is l_{ij}, is passed on the average during the time τ_{ij} consisting of 5 parts:

1) τ_{ij}^{0} - time necessary to cover the distance l_{ij} driving at the driving speed $v_{ij}(t)$;

2) τ_{ij}^{sta} - time wasted braking at the restrictive signals of the traffic lights;

3) τ_{ij}^{st} - time wasted standing by the restrictive signals of the traffic lights;

4) τ_{ij}^{gr} - time wasted to accelerate after standing to the speed $v_{ij}(t)$ [1, 2];

5) τ_{ij}^{st-z} - time wasted a certain road user who „catch up with" the row as the traffic light signal was already green

$$\tau_{ij} = \tau_{ij}^{0} + \tau_{ij}^{sta} + \tau_{ij}^{st} + \tau_{ij}^{gr} + \tau_{ij}^{st-z}. \quad (1)$$

The time τ_{ij}^{st} wasted standing by restrictive traffic light signal consists of two parts:

1) time of standing by the red signal τ_{ij}^{st-r} (from stop to lighting of permissive (green) signal);

2) time τ_{ij}^{st-p} of starting after the permissive (green) signal appears.

That, if traffic lights of the street G_{ij} are tuned in the "green wave" mode, average passing duration of this street (from the first to the last crossroad) is [2]:

$$M\lfloor\tau_{ij}\rfloor = \left(1-\frac{(1+\tau_r n_{ij}(t))T_{raud}}{T_{zal}+T_{raud}}\right)\frac{l_{ij}}{v_{ij}(t)} +$$

$$+ \frac{(1+\tau_r n_{ij}(t))T_{raud}}{T_{zal}+T_{raud}}\left\{2\frac{v_{ij}(t)}{a}\right\} +$$

$$+ \tau_r n_{ij}(t)\frac{T_{zal}T_{raud}}{T_{zal}+T_{raud}} +$$

$$+ \frac{\left(1+\tau_r n_{ij}(t)+(\tau_r n_{ij}(t))^2\right)T_{raud}^2}{2(T_{zal}+T_{raud})} +$$

$$+ \frac{(1+\tau_r n_{ij}(t))T_{raud}}{T_{zal}+T_{raud}}\frac{al_{ij}-(v_{ij}(t))^2}{av_{ij}(t)}, \quad (2)$$

here T_{raud}, T_{zal} – effective duration of red and green traffic light signals [s]; $n_{ij}(t)$ – traffic density [number of vehicles per second]; τ_r – time [s] of the driver's reaction (to starting of a vehicles standing in front of him).

It should be noted that average time of waiting τ_{ij}^{st-z} is calculated by a formula

$$M\lfloor\tau_{ij}^{st-z}\rfloor = \frac{(\tau_r n_{ij}(t))^2 T_{raud}^2}{2(T_{zal}+T_{raud})}. \quad (3)$$

If $M\lfloor\tau_{ij}^{st-z}\rfloor \geq \frac{1}{n_{ij}(t)}$, row of cars by the red signal continually lengthen and develop a gridlock.

This process must be analyzed in separate.

Gridlocks dynamic analysis

There is as situation when the traffic jam are in L km street witch length is L_{sp} km (fig. 2).

The speed in the transport traffic jam is v_1, in the rest distance of the street speed is - $v_0 > v_1$.

The traffic jam between next to transport vehicles is described by formula

$$L = l + 1{,}8\ v_{m/s}. \quad (4)$$

In the rest of the street distance between contiguous vehicle is

$$L_p = L_0 + L_a. \quad (5)$$

where L_0 – a minimal gap between two vehicles when $v = v_0$, $L_a > 0$,

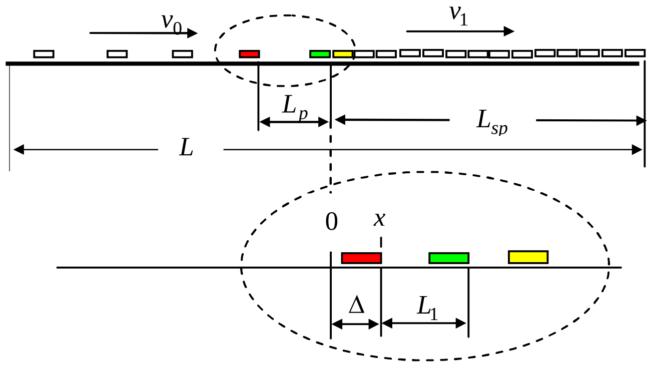

Fig. 2. Marking explanation picture

One vehicle (in Fig.2 is marked with red square) is approaching to transport jam at the point x, which is *Δ* length far from „0“. At this point traffic jam was reached by second vehicle before (in fig.2 is marked with green square). In case when $\Delta > 0$ traffic jam is about to extinct. If $\Delta < 0$ traffic have tendency to growth up.

How to find out Δ length ?

The "green" car distance $\Delta + L_1$ takes in

$$T = \frac{\Delta + L_1}{v_1} = \frac{\Delta + l + 1{,}8v_1}{v_1}, \quad (6)$$

here L – vehicle average length.

Formula (6) works if $v_1 > 0$, this means that traffic jam must move at least average minimal speed. For unmoving traffic jam this formula is useless.

If traffic jam is unmoving – the street transit time numeration has no sense.

The "red" car time T has to intervals: T_0 - when the speed of the car is v_0, and T_s - when the car slow down the speed from v_0 till v_1

$$T = T_0 + T_s. \quad (7)$$

If the car stops constant acceleration *a*, then

$$T_s = \frac{v_0 - v_1}{a}. \quad (8)$$

The distance of the stopping moment

$$S_s = v_0 T_s - \frac{aT_s^2}{2} = \frac{v_0^2 - v_1^2}{2a}. \quad (9)$$

It is easy to see from figure 2 that "red car" goes distance constant speed v_0

$$S_0 = L_p + \Delta - S_s. \quad (10)$$

It takes T_0, time to pass distance S_0, witch one can describe formula (5), (9) and (10),

$$T_0 = \frac{L_0 + L_a + \Delta - \frac{v_0^2 - v_1^2}{2a}}{v_0} . \quad (11)$$

From formula (6), (7), (8) and (11) we get equation

$$\frac{2aL_a + 2aL_0 + 2a\Delta - v_0^2 + v_1^2 + 2v_0^2 - 2v_0v_1}{2av_0} = \\ = \frac{\Delta + l + 1{,}8v_1}{v_1} . \quad (12)$$

Ordered equation

$$\varDelta = \frac{v_1(v_0 - v_1)^2 - 3{,}6av_0v_1 - 2alv_0}{2a(v_0 - v_1)} + \\ + \frac{v_1}{v_0 - v_1}(L_0 + L_a) = b + c(L_0 + L_a) . \quad (13)$$

According to formula (4), $L_0 + L_a = \frac{v_0}{I}$, formula (13) gets form

$$\varDelta = b + cv_0 \frac{1}{I} , \quad (14)$$

here I – intensity of traffic flood till traffic jam limit;

$$b = \frac{v_1(v_0 - v_1)^2 - 3{,}6av_0v_1 - 2alv_0}{2a(v_0 - v_1)} ; \quad (15a)$$

$$c = \frac{v_1}{v_0 - v_1} . \quad (15b)$$

According to formula (6) and (13) can make conclution that the traffic jam is getting shorter by speed.

$$v_{sp} = \frac{\Delta}{T} = \frac{\Delta v_1}{\Delta + l + 1{,}8v_1} , \quad (16)$$

or quantified (14),

$$v_{sp} = \frac{bv_1I + cv_0v_1}{bI + cv_0 + l + 1{,}8v_1} . \quad (17)$$

The traffic jam length is changing linearly.

Passing time of the street G_{ij}

$$T_{ij} = t_{ij-sp} + t_{ij-l} , \quad (18)$$

here t_{ij-sp} – the traffic jam time; t_{ij-sp} – time going street G_{ij} till traffic jam.

The traffic jam speed is v_1, but speed till the traffic jam it is - v_0,

$$T_{ij} = \frac{L_s(0) - v_{sp}t}{v_1} + \frac{L - L_s(0) + v_{sp}t}{v_0} . \quad (19)$$

Transforming the formula (19)

$$T_{ij} = \frac{L}{v_0} + \frac{v_0 - v_1}{v_0v_1}\left(L_s(0) - v_{sp}t\right). \quad (20)$$

The important character of the street $T_{ij} = f(t, I)$ analytic expression get used (20) v_{sp} from formula (17)

$$T_{ij} = \frac{L}{v_0} + \frac{v_0 - v_1}{v_0v_1}\left(L_s(0) - \frac{bv_1I + cv_0v_1}{bI + cv_0 + l + 1{,}8v_1}t\right). \quad (21)$$

It is important to see that $0 < t \leq \frac{L_s(0)}{v_{sp}}$.

Conclusions

1. Traffic jams problem in the cities could be relieved by installation of information systems showing to road users in real time the fastest (the shortest in respect of passing time) routs. Such systems need dynamic *street passing duration's base* for functioning which is possible only after creation of an automatic city transport monitoring system.
2. To evaluate a street passing duration it would be enough to measure average speed of vehicles and traffic density in its characteristic parts.
3. To find street passing durations is possible to use in this article presented methodology.

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The article analyzes a problem of further development of traffic control informational systems in order to present to the road users effective information about the shortest in respect of time routes and thus to improve use of existing city transport infrastructure. To solve this task it is suggested to create dynamic (automatically updated in real time) *street passing durations base*, for support of which a city transport monitoring system operating in real time is necessary consisting of a network of sensors, a data collection communications system and a data processing system. In the article it is shown that to predict a street passing duration it is necessary to measure speed and traffic density in the characteristic points of the street. Measurements of do not significantly improve accuracy of forecast of a street passing time. Methodology are presented meant to forecast a street passing time. Ill. 2, bibl. 4 (in English; summaries in English, Russian and Lithuanian).

М. Дагоцкис, И. Даунорас, В. Багдонас. Система для мониторинга и управления маршрутами в городском транспорте // Электроника и электротехника. – Каунас: Технология, 2009. – № 5(93). – С. 73–76.

Представлены результаты исследования проблемы дальнейшего развития информационных систем, преднзначенных для управления транспортными потоками. Целью такого развития является обеспечение водителей оперативными данными о кратчайших по времени маршрутах и заодно улучшение показателей использования фактической (с учетом временных преград и препятствий) пропускной способности инфраструктуры городского транспорта. Для решения данной задачи предлагается создание динамичной (возобновляемой в реальном времени) базы времен проезда улиц, для функционирования которой необходима система мониторинга движения городского транспорта, состоящая из системы датчиков, коммуникационной сети сбора данных и системы обработки данных. Показано, что для точного прогнозирования времени проезда улицы необходимо иметь данные о скорости и интенсивности транспортного потока в характерных точках вдоль трассы. Представлена методика прогнозирования времени проезда улицы. Ил. 2, библ. 4 (на английском языке; рефераты на английском, русском и литовском яз.).

M. Dagockis, J. Daunoras, V. Bagdonas. Miesto transporto stebėsenos ir maršrutų valdymo sistema // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 5(93). – P. 73–76.

Nagrinėjama eismo valdymo informacinių sistemų tolesnio tobulinimo problema, siekiant eismo dalyviams pateikti operatyvią informaciją apie trumpiausius pagal laiką maršrutus ir taip geriau išnaudoti esamą miestų transporto infrastruktūrą. Šiam uždaviniui spręsti siūloma sukurti dinamišką (realiuoju laiku automatiškai atnaujinamą) *gatvių pervažiavimo trukmių bazę*, kuriai palaikyti reikalinga realiuoju laiku veikianti miesto transporto stebėsenos sistema, susidedanti iš jutiklių tinko, duomenų surinkimo komunikacijų sistemos ir duomenų apdorojimo sistemos. Parodyta, kad gatvės pervažiavimo trukmei prognozuoti reikalinga transporto srauto greičio ir intensyvumo matavimų būdinguose gatvės taškuose sistema. Pateikta metodika gatvės pervažiavimo trukmei prognozuoti. Il. 2, bibl.4 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).